Dec. 20, 1949 P. F. M. GLOESS 2,491,969

ELECTRIC SIGNAL TRANSMISSION SYSTEM

Filed Oct. 14, 1946

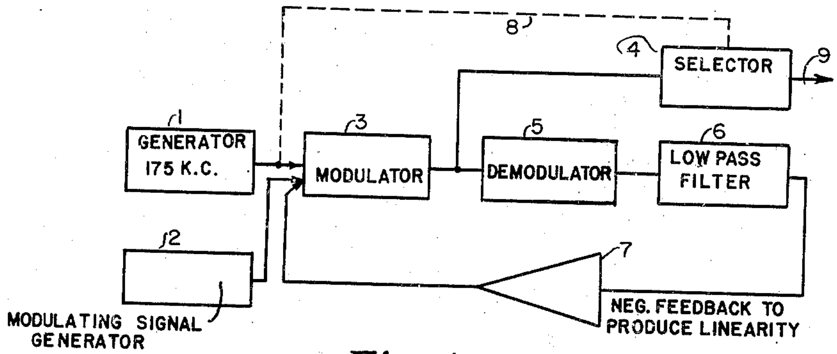

Fig 1

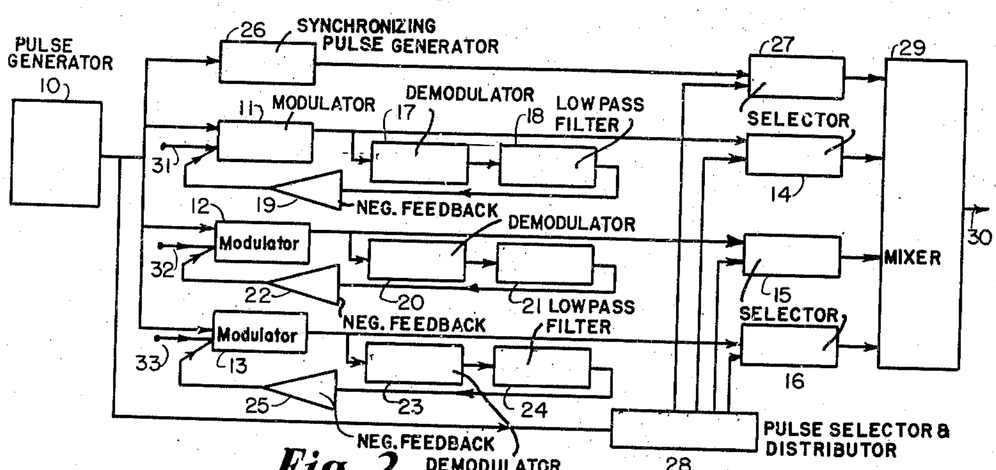

Fig 2

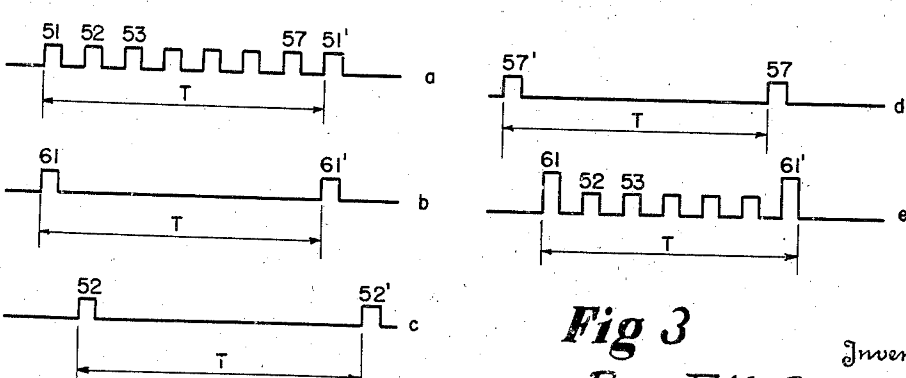

Fig 3

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Patented Dec. 20, 1949

2,491,969

UNITED STATES PATENT OFFICE

2,491,969

ELECTRIC SIGNAL TRANSMISSION SYSTEM

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Application October 14, 1946, Serial No. 703,220
In France October 25, 1945

7 Claims. (Cl. 332—9)

1

My invention relates to systems for transmitting electric signals wherein the signals to be transmitted are used for modifying the particular features such as the amplitude, duration and relative spacing of recurrent series of impulses of a higher frequency. It is known that, in such pulse modulation systems the frequency of the pulses should be at least twice that of the maximum frequency of the modulating signals and the ratio generally adopted for these two frequencies is 2.25 so as to provide the marginal parts for the required filtration without any waste of frequency channels.

In such systems however, a particular difficulty arises for obtaining a transmission of high grade as soon as it is desired to establish a pulse modulator with a very small rate of linear distortion. In practice, with any known arrangement it is possible to obtain distortion rates of the magnitude of 5% for a mean depth of modulation whereas it may sometimes be desired to obtain less than 1%.

It is then possible to make use of the advantages provided by a negative feedback device associated with the modulator. It is known that if the low frequency gain in the feedback loop obtained is equal to $\mu\beta$, μ being the gain of the direct circuit and β that of the negative feedback circuit, the rate of non-linear distortion obtained is divided by the factor $(1+\mu\beta)$.

However for such an arrangement, it is necessary to provide in the direct transmission path beyond the modulator, an auxiliary demodulator of a design similar to that of an ordinary receiver set demodulator, and a low pass filter eliminating undesired frequencies such for instance as the frequency of the difference between the recurrence frequency of the carrier pulses and the highest frequency of the modulating signal, i. e. frequencies of the same magnitude as the higher frequencies of said modulating signal, for the usual above-mentioned ratio of the magnitude of 2.25.

The presence and dimensioning of the low pass filter in the feedback loop produces a delay of transmission which is comparatively important and the amplitude of the phase shifts for the higher frequencies of the band to be transmitted, which may reach in fact phase opposition, limits the gain of the loop to a value less than 1, which leads to a particularly low improvement of the rate of distortion for lower values of said band of frequencies and, actually, to a worse distortion for the higher frequencies to be transmitted.

It seems therefore that the advantage of a

2

negative feedback circuit across a modulator can be obtained only by increasing the frequency of recurrence of the carrier pulses, i. e. by using for transmitting purposes a too much extended high frequency spectrum.

These drawbacks are overcome according to certain features of my invention, while retaining however the advantages of a negative feedback circuit associated with the modulator. This is obtained by the process of modulating, by the signal to be transmitted, a series of impulses the frequency of which is an integral multiple of the frequency of the modulated pulses which will finally be sent on to the transmission system and by picking up modulated pulses at the output, a series of pulses which are repeated at the desired frequency of transmission.

A transmission system for modulating impulses, embodying features of my invention, includes therefore (1) a generator of carrier pulses which are repeated at a frequency $F'=n\times F$, F being the frequency of the modulated pulses which it is desired to transmit in the system; (2) a modulator provided with a negative feedback circuit as described which modulates the pulses of a frequency F' with the modulating low frequency signal; and (3) a pulse selector for picking up from the series of pulses thus modulated, with a reduced rate of distortion at a frequency F', a series of modulated pulses which are repeated at a frequency F and (4) means for sending these pulses at a recurrence frequency F into the transmission circuit.

Such an arrangement is of advantageous application according to a further feature of my invention, to the case of multiplex communications. As a matter of fact, in said case, the periodicity of the pulses at a higher recurrence, as used for modulation, equal to that of the pulses of the complex signal constituted by the combination of the impulses of all the channels.

These features and also other features and the manner of embodying same, will be disclosed with further detail in the following description given by way of example and with reference to accompanying drawings. In said drawings:

Fig. 1 is a diagram illustrating a portion of a simplex transmitter for a pulse modulation system;

Fig. 2 is a diagram of a portion of a multiplex transmitter for a similar transmission.

Fig. 3 shows diagrams of pulses used for explaining the operation.

If it is supposed that the maximum telephonic frequency to be transmitted is for instance 10,-

000 cycles per second, the frequency of the pulses to be considered will be of the magnitude of 25,000 per second. Now if a pulse generator were directly used, operating at this frequency and if it were attempted to apply to the modulator following this generator a negative feedback circuit, the filter of the feedback loop should cut off the frequencies comprised between 1 and 1.5 times the maximum telephonic frequency, i. e. the frequencies above a value comprised between 10,000 and 15,000 cycles per second, and above.

In order to avoid the limitations due to this small difference in frequencies, there is provided according to the invention, a pulse generator the frequency of which is an integral multiple of that of the pulses which are finally transmitted after modulation. In the diagram of Fig. 1 the generator 1 is chosen with a recurrence of pulses which is seven times the recurrence of the pulses to be transmitted; such a series of pulses may be similar to that shown at 51—57 on the curve *a* of Fig. 3.

These pulses are applied to the modulator 3 together with the modulating signal generated by the source 2. This modulator is connected to a negative feedback circuit arrangement through the agency of an auxiliary demodulator 5 of a design similar to that of the usual receiving demodulator. Said demodulator is followed by a low band filter 6 and a negative feedback circuit 7 which may include an attenuator, a phase shifter or a simple connection according to arrangements well known in the art.

The pulses thus modulated are transmitted to a circuit 4 in which is produced a demultiplication, i. e. wherein only one impulse out of seven is allowed to be transmitted through the line 9 towards the subsequent stages as illustrated by the graphs *b* to *d* of Fig. 3.

This wiping out of a number of pulses may be obtained either through purely local means contained in the circuit 4 such as a pulse counting circuit similar to those used in television synchronizing systems, or more advantageously by using the pulses from the generator 1 as pilot pulses. The connection 8 shown in dotted lines supplies these pilot pulses to the circuit 4 that is provided with a circuit such as that disclosed in copending application Serial No. 761,029, filed by Paul Gloess and Gaston Potier on July 15, 1947, for Pulse frequency division and assigned to this assignee.

The frequency of the pulses applied to the modulator 3 in the above described system is $F'=7F$, F being the frequency of the modulated pulses at the output. Supposing F is equal to 25,000 per second, it is apparent that $F'=175{,}000$ per second. Thus the lower stray frequency to be eliminated in the low band filter 6 is $F'-f=$ 165,000 per second, i. e. 16.5 times the value of *f*, the maximum telephonic frequency to be transmitted, instead of 1.5 times as would be the case if the same pulse recurrence were used in the generator 1 and in the output circuit. The cut-off frequency of the filter 6 may thus be increased by eleven times, its transmission time is reduced proportionally as well as the phase shift for the same frequency to be transmitted. It is consequently possible to use a much higher degree of negative feedback, which produces a practically complete elimination of the non-linear distortions affecting the modulation.

A correct dimensioning according to the means used generally in the art, for the circuit elements in the negative feedback loop 7 will in fact result in an improvement by more than ten times of the linearity of the modulation obtained. The rate of distortion is reduced to 0.5%.

It is obviously supposed, in these estimations, that the auxiliary demodulator 5 does not introduce any substantial distortion, which result may be easily reached in practice.

In the case of demodulators producing a predetermined distortion, the negative feedback arrangement may be arranged to correct the distortion in the whole modulator-demodulator unit. It is thus possible to retain the advantage of a negligible rate of distortion for the whole of the transmission, providing however that the demodulators used both for transmission and for reception show a sufficient constancy in their distortion characteristics.

In the case of a multiplex pulse system, several channels such as telephone channels are transmitted simultaneously by using several series of modulated pulses interlaced in time as shown in the diagram *e* of Fig. 3 with a complementary series of unmodulated pulses 6L, 6L' . . . acting as pilot pulses for separating, at the receiver, the pulses belonging to each channel.

For applying the present invention to such arrangements, the periodicity of the pulses used for modulation should be an integral multiple of the final periodicity of the pulses of the complete signal including all the transmission channels together with the pilot channel i. e. in the case of a channel system:

$$F''=K(n+1)F$$

K being any suitable integer.

The selection of this recurrence frequency F'' is obviously limited only by the necessity of retaining, between two consecutive pulses, the time interval indispensable for the subsequent selection operation.

In particular, it may be of advantage to take for *k* a value 1, i. e. to adopt equal values for the recurrence frequency of the pulses used for modulation (Fig. 3 curve *e*) and for that of the complex signal (Fig. 3 curve *e*).

Fig. 2 illustrates diagrammatically an example of application of this invention to a six channel multiplex system, the corresponding pulse diagrams being shown on curves *a* to *e* in Fig. 3.

The pulse generator 10 produces series of pulses of equal amplitudes and equal spacings 51—57, 5L' as illustrated by the curve *a*. It feeds the synchronizing pulse generator 26 with pulses of high frequency. The generator 10 also feeds pulses to the different modulators 11, 12 and 13 together with a pulse selector and distributor 28.

Each modulator 11, 12 and 13 including auxiliary means such as amplifying and amplitude limiting devices, is supplied by signal sources of audio frequency from lines 31, 32 and 33, respectively. The modulator 11 is followed by an auxiliary demodulator 17 followed in turn by a low-pass filter 18. The output of the filter 18 is applied by the negative feedback circuit 19 on the input of the modulator 11. As disclosed, the high frequency of the pulses used for modulation purposes allows the use of a filter the cut-off frequency of which is high with reference to the highest desired telephonic frequency whereby it is possible to make use of an efficient feedback circuit.

The modulators 12 and 13 are followed in turn by similar demodulator, filter and feedback circuits 20, 21, 22 and 23, 24, 25. Each output signal of a modulator thus corrected, is applied to a selecting circuit, 14, 15, 16 wherein the pulses corresponding to each channel are discriminated by means of currents from a circuit 28 which may consist of a pulse selector and distributor of any well known type; it may in fact be virtual i. e. incorporated in each of the selecting circuits 14, 15 and 16. The outcoming signals from the selectors have then a recurrence frequency F as shown for instance on the curves *b*, *c* and *d* for the two first and the last modulator of the system with the corresponding shifts.

The synchronising pulses or pilot pulses at the output of the generator 26 are also demultiplied inside the circuit 27 in a manner similar to the pulses modulated by the signals.

All the pulses passing out of the selectors 14 to 27 are then transmitted to a mixing circuit 29; the shape of a composite signal appearing at 30 at the output terminals of said mixer, may be such as shown on the curve *e* of Fig. 3, the pilot pulses 61, 61' being of same polarity but of a greater amplitude than the modulated pulses 52, 53 of the different channels although any other distinguishing feature such as a reversal of polarity may be used for this purpose. This composite signal may obviously be used as such for the transmission or for modulating suitable output stages.

What I claim is:

1. A method of transmitting modulated pulses comprising generating pulses having a frequency that is an integral multiple of the frequency of the pulses to be transmitted, feeding said pulses to a modulator for modulating said pulses in accordance with signals to be transmitted, feeding part of the output of said modulator to a demodulator for demodulating said part of the modulator output, feeding the output of said demodulator through a negative feedback network to the input of said modulator to improve the linearity of said modulator, and selecting pulses from the other part of said modulator output corresponding to a submultiple of said first mentioned frequency, for transmission.

2. Apparatus for the transmission of modulated pulses comprising a generator for generating pulses of a frequency F' that is equal to *n* times F, F being the frequency to be transmitted, a modulator for modulating said pulses in accordance with signals to be transmitted, a demodulator for demodulating part of the output of said modulator, a low pass filter for passing the signal frequencies from said modulator, a negative feedback network connected between the output of said low pass filter and an input of said modulator for feeding said signals from said low pass filter to said modulator to improve the linearity of said modulator and means for periodically selecting a pulse from the frequency F' of said modulated pulses such that the repetition rate of the selected pulses corresponds to the frequency F to be transmitted.

3. A multiplex transmission system for transmitting modulated pulses comprising a pulse generator for generating pulses of a frequency F', a plurality of modulators connected to the output of said pulse generator, a negative feedback network connected to each of said modulators for improving the linearity thereof, each of said feedback networks including a low pass filter having a cut-off frequency just below the frequency F' whereby the degree of feedback in said feedback networks may be substantially increased and non-linear distortion in said modulators practically completely eliminated, a plurality of selectors, connections for applying the output of each of said modulators to a selected one of said selectors, means connected between said pulse generator and said selectors for timing said selectors, and a mixer connected to said selectors for interlacing the outputs of said selectors into a composite signal to be transmitted.

4. A multiplex transmission system for transmitting pulses comprising a pulse generator for generating pulses, a plurality of modulators connected to said pulse generator, a negative feedback network for each of said modulators for improving the linearity thereof, each of said feedback networks including a low pass filter having a cut-off frequency just below the frequency whereby the degree of feedback in said feedback networks may be substantially increased and non-linear distortion in said modulators practically completely eliminated, a mixer circuit, and means for selecting pulses from the outputs of said modulators in sequence and supplying said pulses in said sequence to said mixer circuit.

5. A multiplex transmission system as set forth in claim 4 further comprising a synchronizing pulse generator and connections for connecting said synchronizing pulse generator to said means for selecting pulses whereby said means selects synchronizing pulses and inserts said synchronizing pulses into the pulse sequence.

6. Apparatus for the transmission of modulated pulses comprising a generator for generating pulses of a frequency F' that is an integral multiple of the frequency to be transmitted, a modulator for modulating said pulses in accordance with signals to be transmitted, a demodulator for demodulating part of the output of said modulator, a low pass filter for eliminating said frequency F', a negative feedback network connected between the out-put of said low pass filter and an in-put of said modulator for feeding the out-put from said low pass filter to said modulator to improve the linearity of said modulator, the cut-off frequency of said low pass filter being increased substantially up to said frequency F' so that the transmission time and phase shift thereof is reduced whereby the degree of negative feedback in said network may be substantially increased and non-linear distortion in said modulator practically completely eliminated, and selecting means for selecting from said modulated pulses a series of pulses having a frequency that is a submultiple of the frequency F' for transmission.

7. Apparatus for the transmission of modulated pulses comprising a generator for generating pulses of a frequency F' that is equal to *n* times F, F being the frequency to be transmitted, a modulator for modulating the pulses of frequency F' in accordance with signals to be transmitted, a demodulator for demodulating part of the output of said modulator, a low pass filter for eliminating the frequencies including the difference between the frequency F' and the highest frequency of the modulating signal, a negative feedback network connected between the out-put of said low pass filter and an in-put of said modulator for feeding the out-put from said low pass filter to said modulator to improve the linearity of said modulator and means for selecting from said modulated pulses a series of pulses having a frequency F for transmission.

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